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**The Effects of Soybean Protein Changes
on Major Agricultural Markets**

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EXECUTIVE SUMMARY

Technology Project Assessment

Purpose. This study investigates the likely impacts of biogenetically increasing the protein content of soybean. The purpose is twofold: (a) to identify the linkages among the associated sectors, and to quantify the probable impacts by sector, and (b) to illustrate appropriate procedures for assessing potential technological improvements.

Method. This is a comparative static simulation, based on *with-and-without* case analysis. The baseline case simulates the 1985-89 performance. This is compared with a simulation of what would have been the case, if soybean protein content had been higher, 39 percent, instead of the historical 1985-89 average of 35 percent.

Assumption: Two extreme possibilities were studied, one assuming that U.S. exports fully adjust as a result of complete adoption of new technology abroad, and the other with unchanged export levels.

Results. U.S. crop producers benefit; corn producers gain more than soybean producers. Increased corn demand elevates both production and price. The soybean yield decline is responsible for increased acreage. However, production is lowered and the reduced supply increases price. The soybean processing sector suffers substantially. The livestock sector as a whole improves with the benefits in poultry and swine exceeding the losses in cattle. The livestock-consumer surplus improves by close to \$1 billion, but oil consumers' surplus loss of almost twice that amount results in an overall consumer loss. There are some specific results of the more likely case of the full export sector adjustment scenario.

\$ Increased soybean protein directly translates into high-value soybean meal. This enables feed cost reduction without compromising feed-to-meat conversion efficiency. The corn-soybean meal substitution that provides this cost reduction has both a positive and a negative impact on demand for soybean meal.

\$ Likewise, the increase in soybean protein has two opposing influences on soybean meal supply: it decreases yield per acre, but increases meal yield for each bushel of beans crushed.

\$ Soybean area increases from 60.3 to 63 million acres. However, production declines by 5 percent due to yield reduction and results in higher prices. Soybean producers are likely to improve their net income by \$ 0.4 billion annually from a baseline level of \$ 7.3 billion. Higher demand for corn raises acreage and price, resulting in a 0.9 billion dollar boost in corn producer returns over cash costs.

\$ Producer returns are favorable in the poultry and swine industries (about \$ 0.3 million increase in each) due to feed cost reduction and increased operational levels, but the beef industry loses \$ 0.4 billion.

\$ Total farm producer surplus is likely to improve by \$ 1.6 billion from a baseline level of \$ 95 billion.

\$ Soyoil production suffers on two counts, lower soybean yield and lower oil yield in milling. A 50 percent increase in oil price is predicted.

\$ Soybean processor revenues drop by \$0.5 billion due to declines in both volume and value of soybean meal.

Note. This assessment method differs from earlier studies in its coverage of sectoral linkages and consideration of market-level responses. This allows us to quantify the gains and losses of each of the market participants. While only two specific scenarios are compared in the report, the analytical system has been set up for easy analysis of almost any alternative scenario; for example, if protein content can be increased with only half the yield or oil content loss. User-friendly Lotus 1-2-3 macros have been created to automatically provide summary tables as well as detailed information on all pertinent changes in each of the markets. Further, several component programs (for optimizing soybean processing revenues, detailed life-cycle feed rationing) have also been set up as user-friendly, menu-driven programs.

Concerns. There is the possibility of transitory advantage to early adopters. Also, a source of permanent advantage is if high protein soybean varieties will be location-specific. Such product differentiation can be further extended to producing distinct varieties for the three different types of livestock. The current model can be modified to consider these possibilities and, in a dynamic setting, to capture the transitory benefits.

THE EFFECTS OF SOYBEAN PROTEIN CHANGES ON MAJOR AGRICULTURAL MARKETS

Technologists can manipulate products for more desirable market characteristics (Harlander, B. Miller and Steenson, 1991). Discussions of the possibilities for soybeans usually include a protein increase. This change could involve various economic gains and losses. Previous studies identified some effects, including reduced feed costs for livestock producers, higher meal yields and profits for soybean processors, and lower yields for producers (AgExpt St.; McVey et al.). But research is incomplete because market-level effects have not been examined. Changes in protein supply and demand could be large enough to influence the price. Further, the close competition with corn for land and markets could offset the effects in the protein market. Finally, the concomitant changes in soybean and soyoil yields could also affect the equilibrium levels and prices in the related sectors.

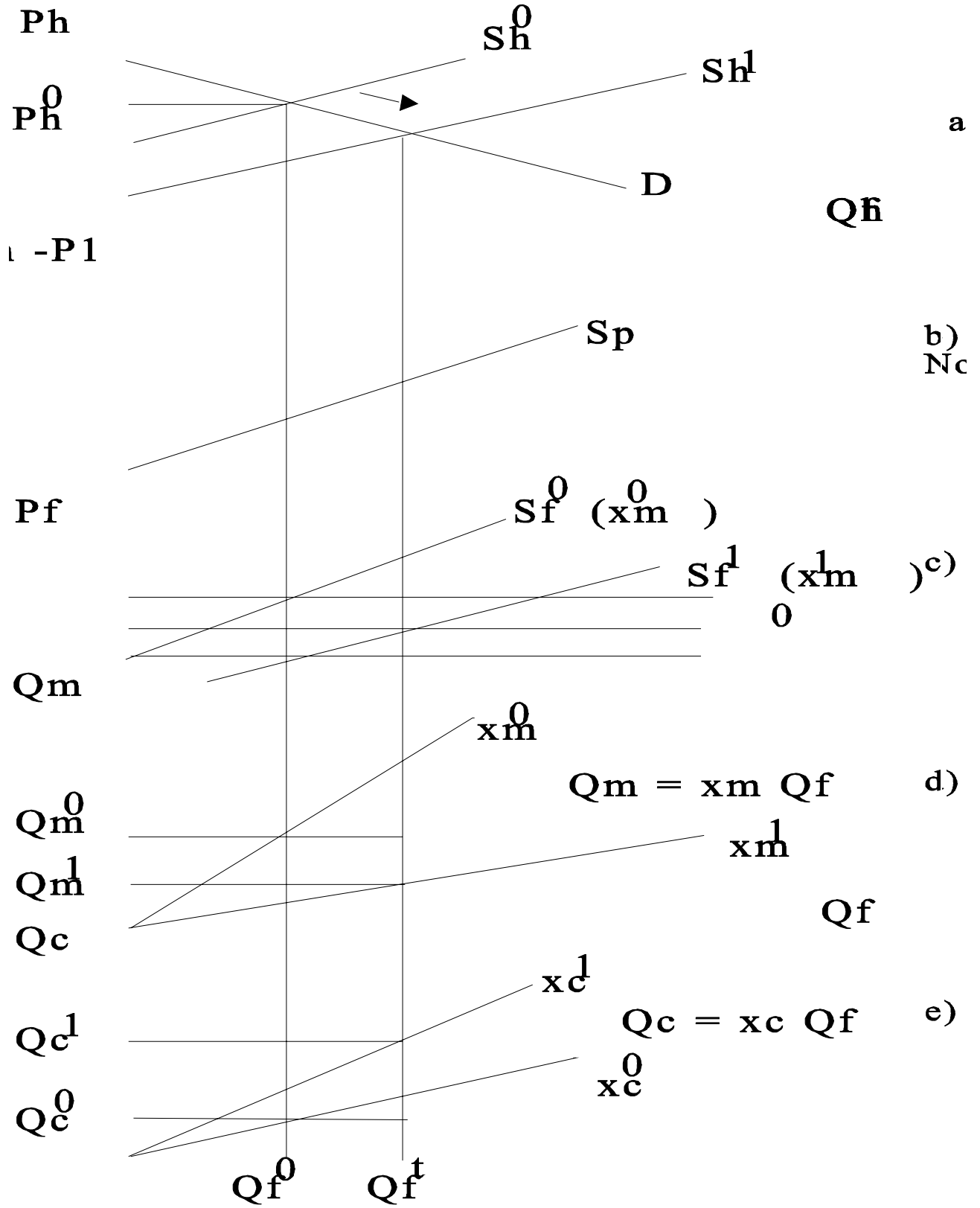
Estimates of the market effects and the distribution of economic benefits among the affected sectors are summarized in this paper. First, major effects on markets are reviewed. Then procedures for combining separate influences are discussed and market effects are summarized. The benefit estimates provide a foundation for technology evaluation.

Changing Production Conditions and Market Effects

There are three major effects that originate with feed suppliers, soybean processors, and producers.

Livestock, Formula Feed, and Grain Market Relationships

One major effect of a protein change originates with formulae feed manufacturers. They sell at marginal costs in a competitive feed market, with corn and soybeans as the dominant ingredients. The formula feed supply schedule is horizontal when corn and soybean prices are given. Upward sloping feed supply schedule (Figure 1, panel C) results from less than perfectly elastic corn and meal supplies. Formula feed (Q_f) is used for livestock production (Q_h) with a fixed meat yield per unit of feed, Y_h . The processing supply schedule S_p is an upward sloping function of the meat processing margin (panel b). In



turn, the livestock supply schedule (S_h in panel a) is the vertical addition of P_f and S_p . Initially, the meat market clears at P_h^0 , which is defined by the intersection of meat supply and demand.

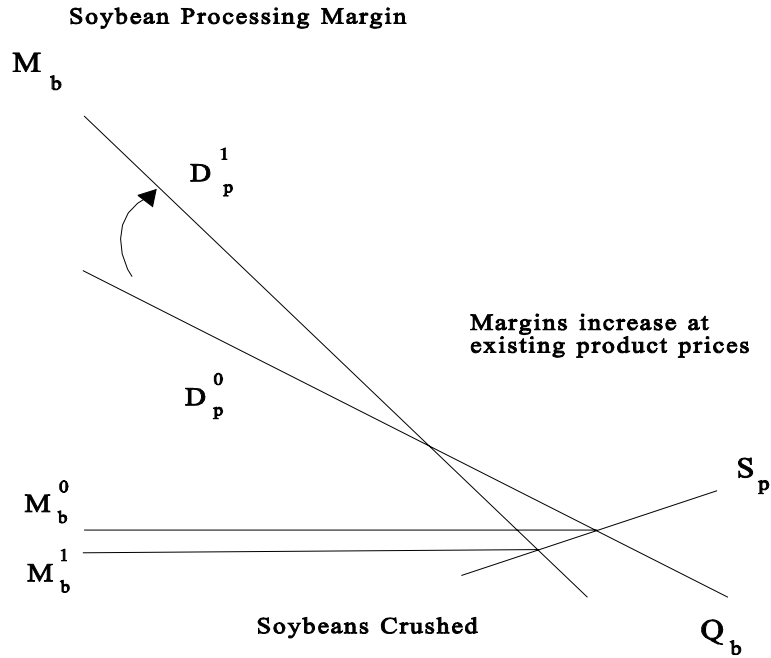
The protein increase shifts the formula feed supply schedule downward from S_f^0 to S_f^1 . This cost reduction occurs because the protein restriction in a linear program of feed ingredients is satisfied with fewer units of more concentrated soymeal. Less expensive corn is added to offset the energy loss associated with the soybean meal reduction. The feed cost reduction carries through livestock and meat processing, so meat supply increases and meat price falls. The meat expansion implies increased feed demand (Q_f^1) but the composition of feed mix changes. The proportion of meal declines, and may even offset the feed expansion for a decline in meal demand (Q_m^1 in panel d). Corn expands, maybe more than proportionately, against feed demand (panel e). Overall, the feed cost effect may work towards meal price declines and corn price increases. (See Appendix A for derivation of the feed supply.)

Soybean Processors: Market Allocations, Revenues and Profits

Meal yields increase when soybean processors crush beans with higher protein content (Brumm and Hurburgh). The protein concentration of the meal also increases. However, oil yield declines. Processors' margin increases at existing prices. Yet product revenue changes depend on elasticities in the respective product markets, as in the price discrimination problem. For instance, a meal volume increase and an oil volume decrease when the meal market is inelastic and the oil market is elastic will reduce processors' revenues. But now consider the demand for soybean processing (D_p in Figure 2), which reflects the declines in meal and oil prices as soybean processing and product marketing increase. This demand curve rotates with a protein increase. The rotation reflects an upward pressure due to increased value per unit of bean crushed, and a countering reduction in demand due to lower meal concentration in feed mix and lowered oil yield. Direction of change in processor margin is then dependent on the position of the supply schedule. The figure shows the possibility of reduced margin and crush volume due to increased soybean protein. A downward rotation with low-cost processors encourages a decrease in soybean price.

Soybean Producers

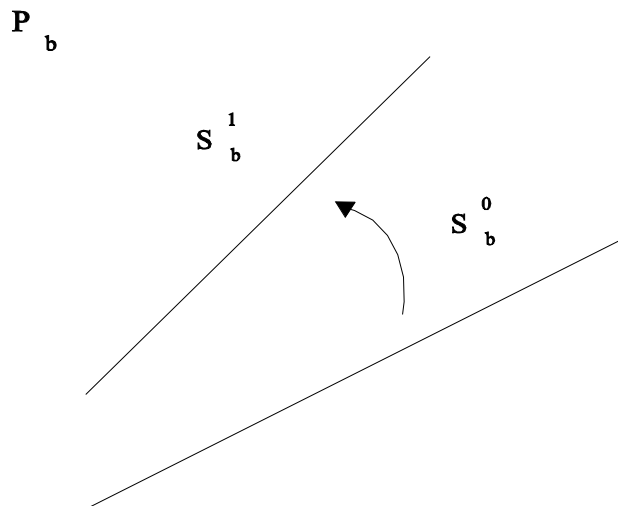
Many agronomists believe that protein increase tends to reduce crop yields and there is some evidence favoring this view (AgExpt St). Suppose that producers decide how many acres to plant by comparing marginal revenues and costs for acreage increases. The yield decrease reduces the revenues



from a unit of land and forces some of the high-cost land out of production. Thus, a supply function, which shows the relationship between soybean production and soybean price (Q_b and P_b in Figure 3), shifts upwards. Hence, the soybean yield effect encourages increases in the soybean price.

Simulation

The outcome of these complex interactions among meat, oil, food processing and grain sectors



depends on supply and demand relationships in all markets. A static simulation model, which focuses on market equilibrium before and after the technology change, was developed. Vertical market relationships are based on product-input yields (soybeans-meal, meal and corn-feed, and feed-meat) that are fixed. A generic version with one meat product and one formula feed is shown in Table 1.

The protein increase is simulated in a two-stage process. First, a fall in the meal share (x_m) and an increase in the corn share (x_c) measure the feed cost effect. The proportions are determined by least cost rations before and after the soybean protein change. Feed ration specifications for poultry, cattle, and swine, as well as the ingredient compositions, were obtained from the specialists at the Department of Animal Science at Iowa State University (ISU). The information from ISU was used to formulate cost minimizing rations presented in Table 2. Appendix B considers the programming problem, the ingredient proportions and feed supply schedules in detail. Second, an increase in meal yield (Y_m) and a reduction in oil yield (Y_o) measure the effect on soybean processors. The yield changes are obtained from soybean processing models that are discussed in Appendix C. Finally, a soybean yield (Y_b) change is obtained from estimates given in AgExpt St.

The magnitude of yield and ingredient changes is defined by levels of protein content. Initially, soybeans with 35 percent protein give soybean meal with 44 percent protein (SBML44) when processed. The new soybeans have a 39 percent protein content and yield 48 percent protein meal (SBML48). Supply and demand relationships refer to the 44 percent meal (35 percent beans) before the protein change, which is the baseline scenario. Afterwards, supply and demand functions refer to the higher protein concentrations.

Execution of the simulation requires attention to several other factors. The empirical model was extended to include the major meat products C poultry, beef, and pork C and formula feeds/ingredients for each type of livestock. Elasticities from other studies provide estimates of relevant market relationships. Many of these estimates are provided by the Center for Agricultural and Rural Development(CARD). But other studies provided estimates of long-run livestock supply response and demand relationships for edible oils (Burr, 1992; Meilke and Griffith, 1981). Linear supply X and

Table 1. Supply and demand relationships in the livestock, feed, soyoil and grain sectors

1)	P_h	$= \alpha_d^h - \beta_d^h Q_h$	(meat demand)
2)	$P_h Y_h - P_f$	$= \alpha_p^h - \beta_p^h Q_h$	(meat processing)
3)	Q_h	$= Y_h Q_f$	(feed demand)
4)	P_f	$= x_c P_c + x_m P_m$	(feed supply price)
5)	Q_c	$= x_c Q_f$	(corn demand)
6)	P_c	$= \alpha_s^c + \beta_s^c Q_c$	(corn supply)
7)	Q_m	$= x_m Q_f$	(meal demand)
8)	P_o	$= \alpha_d^o - \beta_d^o Q_o$	(oil demand)
9)	$P_m Y_m + P_o Y_o - P_b$	$= \alpha_p^s + \beta_p^s Q_b$	(bean processing)
10)	Q_m	$= Y_m Q_b$	(meal supply)
11)	Q_o	$= Y_o Q_b$	(oil supply)
12)	P_b	$= \alpha_s^s / Y_b + (\beta_s^s / Y_b^2) Q_b$	(bean supply)

Variable Definitions

Endogenous

Q_h	:	meat quantity
P_h	:	meat price
Q_f	:	feed quantity
P_f	:	feed price
Q_c	:	corn quantity
P_c	:	corn price
Q_m	:	meal quantity
P_m	:	meal price
Q_o	:	oil quantity
P_o	:	oil price
Q_b	:	bean quantity
P_b	:	bean price

Exogenous

Y_h	:	meal yield in feed processing
x_c	:	corn proportion in formula
feed		
x_m	:	meal proportion in formula
feed		
Y_m	:	meal yield in soybean
processing		
Q_c	:	corn quantity
P_c	:	corn price

$\alpha=s$ and $\beta=s$ are the intercept and slope parameters of the respective linear functions.

Table 2. Least cost feed ration: Restrictions and ingredient composition as percentage of mix

Restriction			Ingredients			
a. Chickens						
Description	Level	Units	Corn c	Soymeal m	Fat t	Additives a
Protein	28	percent	$\alpha_p = 8.8$	$\beta_p = 44^1$	0	0
Energy	2,850	kcal/kg	$\alpha_c = 3,350$	$\beta_c = 2,230$	$\gamma_c = 8,150$	0
Additive	0.5	percent	0	0	0	$P_a = 1$
Summation	100	percent	$\alpha_s = 1$	$\beta_s = 1$	$\gamma_s = 1$	$P_s = 1$
b. Cattle						
Description	Level	Units	Corn	Soymeal	Urea	Additives
Protein	12.8	percent	$\alpha_p = 8.8$	$\beta_p = 44$	$\gamma_p = 265$	0
Energy	3,090	kcal/kg	$\alpha_c = 3,350$	$\beta_c = 2,230$	0	0
Urea Substitution ²	0	percent	0	$\beta_u = 44$	$\gamma_u = 5235$	0
Additives	5.0	percent	0	0	0	$P_a = 1$
Summation	100	percent	$\alpha_s = 1$	$\beta_s = 1$	$\gamma_s = 1$	$P_s = 1$

¹Program was run parametrically for soybean protein values ranging from 35 to 40 percent at 0.5 intervals, and β_p values were internally determined at each soybean protein level.

$$\frac{\gamma_p U}{(\beta_p S + \gamma_p U)} = .523; \quad (\beta_p S + \gamma_p U) = \frac{\gamma_p U}{.523}; \quad \beta_p S + \gamma_p U \left[1 - \frac{1}{.523} \right] = 0;$$

$$\gamma_p \left[1 - \frac{1}{.523} \right] = 265 \left(1 - \frac{1}{.523} \right) = -235.$$

²Restriction that urea cannot exceed 52.3 percent of total of SBML and urea protein. Imposing it as an equality constant,

c. Swine						
Description	Level	Units	Corn	Soymeal	Urea	Additives
Protein	15.97	percent	$\alpha_p = 8.8$	$\beta_p = 44$	$\gamma = 12$	0
Whey Substitution ³	.066(15.97)	percent	0	0	$\gamma_w = 1$	0
Additives	2.26	percent	0	0	0	$P_a = 1$
Summation	100	percent	$\alpha_s = 1$	$\beta_s = 1$	$\gamma_s = 1$	$P_s = 1$

³Whey protein should account for at least 6.6 percent of total protein in life cycle ration.

demand relations were developed from elasticities and a baseline set at 1985 to 1989 average input and output levels. Elasticities, feed conversion, and yields used in the simulation are summarized in Table 3.

Estimates of export relationships for beans and meal were also available. But our analysis is less detailed. The meal demand function is based on 44 percent meal and the corresponding price. As a first approximation, a user should be indifferent between 1 pound at price P_m and .44 lb. of pure protein at price $(1/.44)P_m$. Then the equivalent demand for 48 percent meal is $(.44/.48)$ pound at a price of $(.48/.44) P_m$. Thus, the meal quantity exported should fall at an equivalent price when concentration rises to 48 percent. Bean export changes the result from meal and oil yield changes and adjustments to foreign processing margins in a fashion that is similar to the domestic processing analysis. Also, the effects of changing bean prices on foreign soybean production were taken into account. The yield reduction that is associated with the new protein varieties is also included as part of international producers' supply response. In short, it is assumed that foreign producers, processors, and feed manufacturers all adopt the high protein soybean variety. An extreme alternative is to totally insulate the foreign sector, and then exports remain unchanged at the baseline level. This scenario was also simulated as a point of reference.

Results

The results of the simulation are given in Tables 4 and 5. Table 4 summarizes the supply, demand, and price changes in crop, feed, and livestock markets equilibrium that are associated with the protein change. Table 5 indicates how the change affects producer profits, processor profits and consumer surpluses. The results of both tables are presented with Case 1 and without Case 2 adjustment in the export market.

Turning to Table 4, the market adjustments generally suggest a reduction in feed costs and expansion in meat output and consumption, with the expansion favoring poultry and pork producers. The formula feed consumption expands, especially for poultry and swine. The feed composition shifts toward corn and away from soybean meal. Corn demand expands and causes rising prices. Soybean meal and crush demand decline but soybean prices still increase due to the yield reduction that is associated with the protein increase.

There are a few major differences between results with and without export adjustments. First, the meal export level is lower when exports adjust because fewer units of the more concentrated meal are required. Second, the soybean price increase is larger when exports adjust because overseas producers also experience a yield reduction when they adopt the high protein varieties. In turn, soybean crush, meal production, and oil production are all lower when the export markets adjust, owing to the squeeze on domestic processors' margin.

Table 3. Elasticities and conversion factors used in the simulation

Description	Prices								Conversion Factor	Details	Source
	Chicken	Beef	Pork	Feed	Corn	Soybean	Soymeal	Soy oil			
<u>Meat demand</u>											
Chicken	!0.6373	0.2686	0.3443								Meyers, 1991
Beef	0.2521	!0.593	0.0954								Meyers, 1991
Pork	0.0585	0.4671	!0.8804								Meyers, 1991
<u>Meat Supply</u>											
Chicken	0.07			!0.017							Buhr 1992
Beef		0.95		!0.53							Buhr, 1992
Pork			0.73	!0.43							Buhr, 1992
<u>Feed demand</u> (computed using constant feed-to-meat conversion ratios)											
Poultry									2.1	lb feed/lb of chicken produced	USDA
Cattle									6.53	lb feed/lb of beef produced	USDA
Swine									9.17	lb feed/lb of pork produced	USDA
<u>Corn block</u>											
Acreage					0.35	!0.052					Meyers, 1991
Production									100.246	yield: bu corn per ac	Meyers, 1991
<u>Soybean block</u>											
Acreage					!0.442	0.618			60.3	yield: bu soybeans per ac	Meyers, 1991
Production											Meyers, 1991
Crush demand						!1.95	1.5	0.74			Meyers, 1991
Meal prod.											
Oil production									47.569	yield: lb meal per bu beans	Meyers, 1991
Domestic oil demand									11.072	yield: lb oil per bu beans	Meyers, 1991
									!0.26		Meyers, 1991
<u>Export demand</u>											
Corn (LR)					!0.65	0.17	0.04				
Soybeans (LR)						!0.44	0.98	0.53			
Soy oil						3.35	!3.02	12.3			
Soybean meal					2.11	1.25	!1.73	!0.76			